Title : will be set by the publisher
Editors : will be set by the publisher
EAS Publications Series, Vol. ?, 2011

RADIATION PRESSURE FEEDBACK IN GALAXIES

Brett H. Andrews[1] and Todd A. Thompson[1, 2]

Abstract. We evaluate radiation pressure from starlight on dust as a feedback mechanism in star-forming galaxies by comparing the luminosity and flux of star-forming systems to the dust Eddington limit. The linear $L_{\rm FIR}$–$L'_{\rm HCN}$ correlation provides evidence that galaxies may be regulated by radiation pressure feedback. We show that star-forming galaxies approach but do not dramatically exceed Eddington, but many systems are significantly below Eddington, perhaps due to the "intermittency" of star formation. Better constraints on the dust-to-gas ratio and the CO- and HCN-to-H_2 conversion factors are needed to make a definitive assessment of radiation pressure as a feedback mechanism.

Observations show that the star formation efficiency per free fall time is only ∼1% (Kennicutt 1998), likely caused by the injection of energy/momentum into the ISM by massive stars ("feedback"). The radiation pressure associated with the absorption/scattering of UV/optical light from massive stars by dust grains has been suggested as the dominant feedback mechanism in star-forming galaxies (Thompson *et al.* 2005 [T05]; Krumholz & Matzner 2009; Murray *et al.* 2010 [M10]; Andrews & Thompson 2011 [AT]). If radiation pressure on dust dominates feedback, then galaxies and their star-forming subregions should approach the dust Eddington luminosity: $L_{\rm Edd} = (4\pi G c M_{\rm g})/\kappa_{\rm F}$, where $M_{\rm g}$ is the gas mass in the region of interest and $\kappa_{\rm F}$ is the flux-mean opacity, which depends strongly on the column density of the medium [T05], varying from $\sim 10^3$ cm^2/g in regions that are marginally optically thin to UV light to a constant value of ∼few–10 cm^2/g in regions that are optically-thick to the re-radiated FIR. In the latter, the $\kappa_{\rm F}$ depends linearly on the dust-to-gas ratio since more dust implies a higher efficiency of momentum coupling to the gas.

$L'_{\rm HCN}$ is proportional to the dense gas mass of galaxies, which is expected to be optically-thick, and $L_{\rm FIR}$ traces the bolometric luminosity of star formation. Thus, radiation pressure feedback predicts a linear correlation between these two

[1] Department of Astronomy, The Ohio State University; e-mail: `andrews@astronomy.ohio-state.edu` & `thompson@astronomy.ohio-state.edu`
[2] The Center for Cosmology and Astroparticle Physics, The Ohio State University

DOI: (will be inserted later)

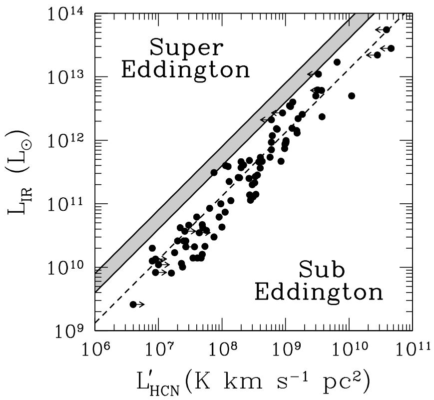

Fig. 1. IR luminosity vs. HCN line luminosity. The lines show the optically thick Eddington limit for our preferred value of the dust opacity (gray region) and for an enhanced dust-to-gas ratio (dashed line) as is seen in some dusty starbursts.

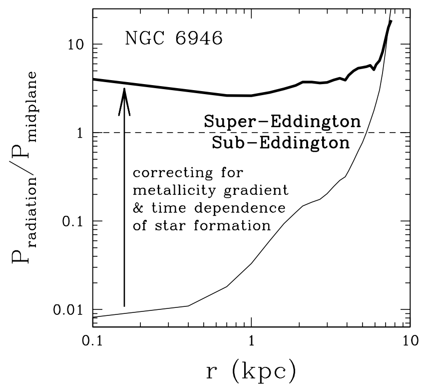

Fig. 2. Eddington ratio ($P_{\rm rad}/P_{\rm mid}$) vs. radius in NGC 6946 (thin line). The arrow shows the effect of correcting the Eddington ratio (thick line) for a metallicity gradient and the intermittent nature of star-forming disks.

quantities, in good agreement with Figure 1. Over ∼4 dex in dense gas mass, star-forming galaxies approach but do not exceed Eddington. We find similar results for the $L_{\rm IR}$–$L'_{\rm CO}$ relation and the Schmidt law, but these relations are complicated by the intermittency of star formation in normal spirals—the tendency for subregions to dim on a timescale that is short relative to the time between star-forming events.

Figure 2 shows the Eddington ratio ($P_{\rm radiation}/P_{\rm midplane}$) as a function of radius in a local spiral (NGC 6946; Leroy *et al.* 2008). At small radii, radiation pressure is significantly subdominant compared to the midplane pressure required to support the gas disk. This discrepancy can be overcome if we account for intermittency and a metallicity gradient in NGC 6946, since a metallicity gradient would likely increase the dust-to-gas ratio and decrease the CO-to-H_2 conversion factor. These two factors, along with the HCN-to-H_2 conversion factor, are the primary observational uncertainties in this analysis, and better constraints on them are needed to definitively assess radiation pressure on dust as a feedback mechanism (see AT for details).

References

Andrews, B. H., & Thompson, T. A. 2011, ApJ, 727, 97 [AT]

Kennicutt, R. C., Jr. 1998, ApJ, 498, 541

Krumholz, M. R., & Matzner, C. D. 2009, ApJ, 703, 1352

Leroy, A. K., Walter, F., Brinks, E., Bigiel, F., de Blok, W. J. G., Madore, B., & Thornley, M. D. 2008, AJ, 136, 2782

Murray, N., Quataert, E., & Thompson, T. A. 2010, ApJ, 709, 191 [M10]

Thompson, T. A., Quataert, E., & Murray, N. 2005, ApJ, 630, 167 [T05]